Phi meson propagation in a hot hadronic gas

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Introduction

Quark-Gluon Plasma

$\Downarrow$

Enhanced production of strange quarks

$\Downarrow$

Enhancement of strange particles (K, ϕ, Λ, Ω)

Introduction

ϕ is a nice probe: $\longleftarrow$ A. Shor, P.R.L. 54 (1985) 1122

- ϕ production in pp and πp is OZI suppressed
- Coalescence: $s\bar{s} \longrightarrow \phi$
- ϕ is not masked behind other resonances
- it can be detected using both kaon pairs (K^+K^-) and dileptons (e^+e^-, $\mu^+\mu^-$)

Introduction

- Widely accepted that ϕ's have a large mean free path in a hot hadronic matter

For example (K. Haglin, N.P.A 584 (1993) 719):

$$\lambda\ (T = 200 \text{ MeV}) = 4.4 \text{ fm}$$
$$\lambda\ (T = 150 \text{ MeV}) = 14 \text{ fm}$$
$$\uparrow$$

Phenomenological Lagrangians with couplings extracted from observed partial decay rates

$$\Updownarrow$$

Many mechanisms that include vertices allowed by the symmetries of QCD, like $\phi K^* K$ or $\rho K^* K^*$, are not taken into account.

Hidden Local Symmetry Lagrangian

- Vector mesons ρ, ω, K^*, ϕ are the gauge bosons of the hidden local U(3)$_{\mathrm{V}}$ symmetry.

  M. Bando, T. Kugo, K. Yamawaki, P.Rep. 164 (1988) 217

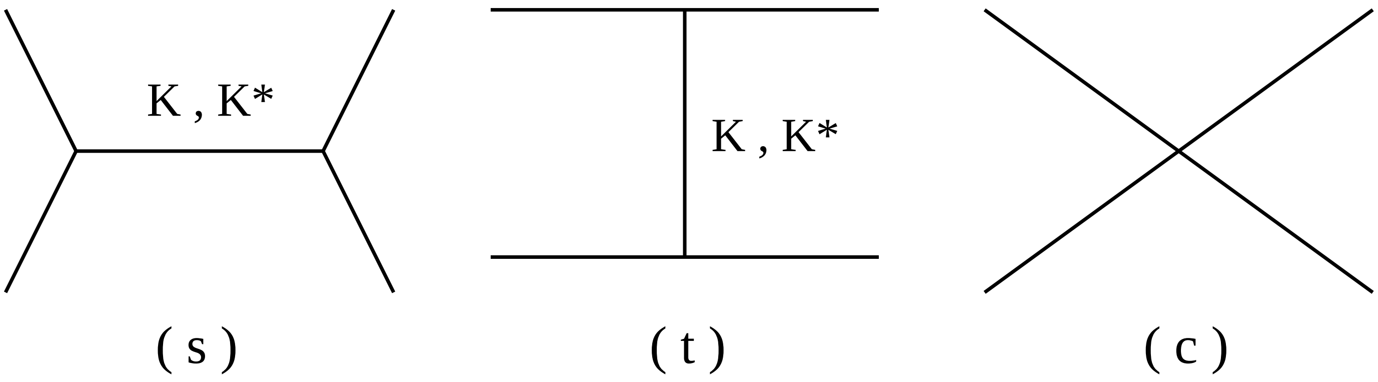
- Spontaneous symmetry breaking $\Rightarrow m_V$

$$m_V^2 = 2g^2 f_\pi^2 \; , \qquad g^2 \leftarrow VPP \text{ coupling}$$

- Flavor symmetry breaking $\Rightarrow$ different couplings
- Anomalous part of the Lagrangian $\Rightarrow VVP$ vertex
- Kinetic term for vector mesons $\Rightarrow$ VVV and $VVVV$ vertices:

Binary reactions

- Relevant vertices: VPP, VVP, VVV, $VVVV$



- No direct couplings of ϕ with π, ρ or ω (OZI rule)

Binary reactions

No.	Reaction	Channels
1.1	$\phi + \pi \rightarrow K + K$	$\mathbf{t}(K^*)$
1.2	$\phi + \pi \rightarrow K + K^*$	$\mathbf{t}(K, K^*)$
1.3	$\phi + \pi \rightarrow K^* + K^*$	$\mathbf{t}(K, K^*)$

Binary reactions

No.	Reaction	Channels
2.1	$\phi + K \to \pi + K$	s,t(K^*)
2.2	$\phi + K \to \rho + K$	s,t(K, K^*)
2.3	$\phi + K \to \omega + K$	s,t(K, K^*)
2.4	$\phi + K \to \phi + K$	s,t(K, K^*)
2.5	$\phi + K \to \pi + K^*$	s(K, K^*),t(K^*)
2.6	$\phi + K \to \rho + K^*$	s,t(K, K^*)
2.7	$\phi + K \to \omega + K^*$	s,t(K, K^*)
2.8	$\phi + K \to \phi + K^*$	s,t(K, K^*)

Binary reactions

No.	Reaction	Channels
3.1	$\phi + \rho \to K + K$	t(K, K^*)
3.2	$\phi + \rho \to K + K^*$	t(K, K^*)
3.3	$\phi + \rho \to K^* + K^*$	t(K, K^*),c

Binary reactions

No.	Reaction	Channels
4.1	$\phi + \omega \rightarrow K + K$	**t**(K, K^*)
4.2	$\phi + \omega \rightarrow K + K^*$	**t**(K, K^*)
4.3	$\phi + \omega \rightarrow K^* + K^*$	**t**(K, K^*),**c**

Binary reactions

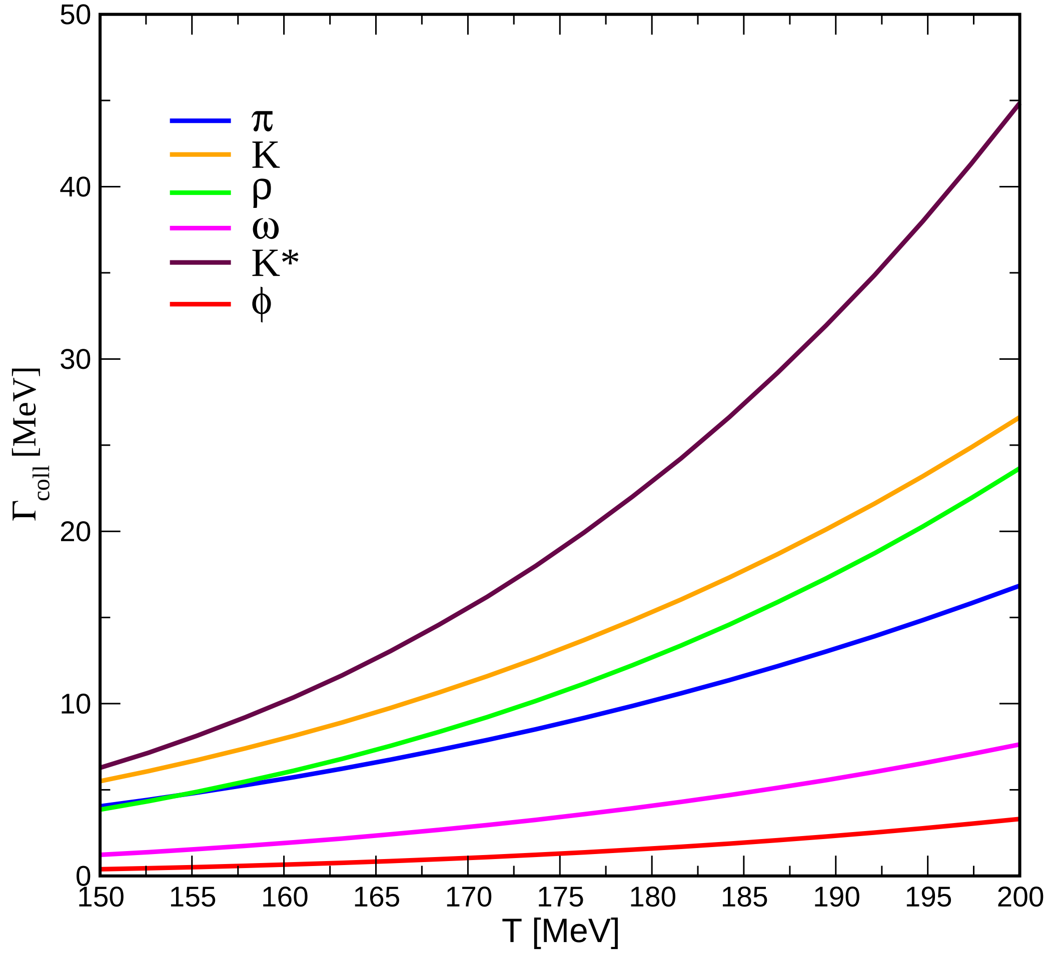
No.	Reaction	Channels
5.1	$\phi + K^* \rightarrow \pi + K$	s(K^*),t(K, K^*)
5.2	$\phi + K^* \rightarrow \rho + K$	s,t(K, K^*)
5.3	$\phi + K^* \rightarrow \omega + K$	s,t(K, K^*)
5.4	$\phi + K^* \rightarrow \phi + K$	s,t(K, K^*)
2.5	$\phi + K^* \rightarrow \pi + K^*$	s,t(K, K^*)
5.6	$\phi + K^* \rightarrow \rho + K^*$	s,t(K, K^*),c
5.7	$\phi + K^* \rightarrow \omega + K^*$	s,t(K, K^*),c
5.8	$\phi + K^* \rightarrow \phi + K^*$	s,t(K, K^*),c

Binary reactions

No.	Reaction	Channels
6.1	$\phi + \phi \rightarrow K + K$	t(K, K^*)
6.2	$\phi + \phi \rightarrow K + K^*$	t(K, K^*)
6.3	$\phi + \phi \rightarrow K^* + K^*$	t(K, K^*),c

Collision rates

$$\Gamma_{coll}^{(a)} = n_a \langle \sigma_{\phi a} v_{rel} \rangle \qquad a = \pi,\ K,\ \rho,\ \omega,\ K^*,\ \phi$$



Collision rates

- Why $\Gamma_{coll}^{(K^*)} > \Gamma_{coll}^{(K)}$?

$$\frac{n_{K^*}}{n_K} = \left.\frac{3m_{K^*}^2 K_2(m_{K^*}/T)}{m_K^2 K_2(m_K/T)}\right|_{T=200\text{ MeV}} = 0.77 \leftarrow$$

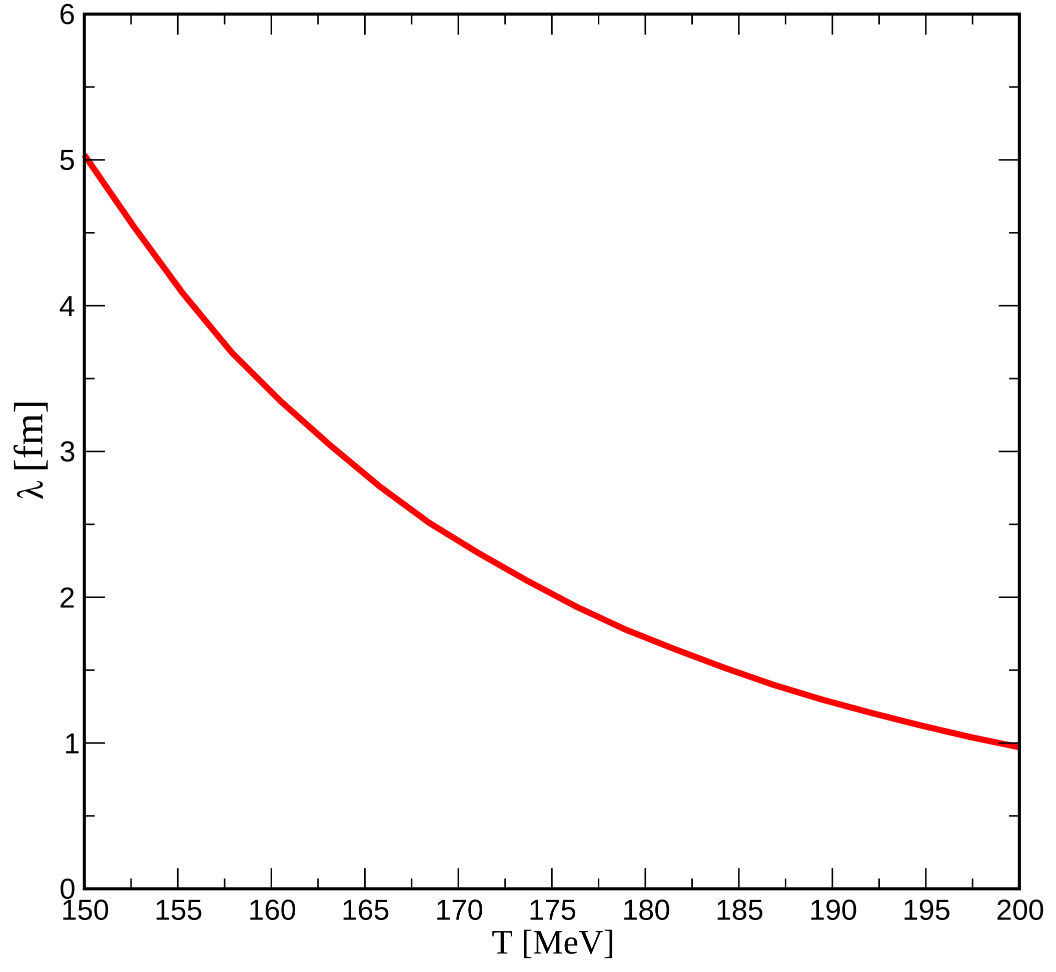
not so small

- Large contributions to $\sigma_{\phi K^*}$ from:

$$\phi + K^* \rightarrow \rho + K^*$$
$$\phi + K^* \rightarrow \omega + K^*$$
$$\phi + K^* \rightarrow \phi + K^*$$

- Inelastic reactions account for $>$ 80 % of Γ_{coll}

Mean free path



Very short mean free path !

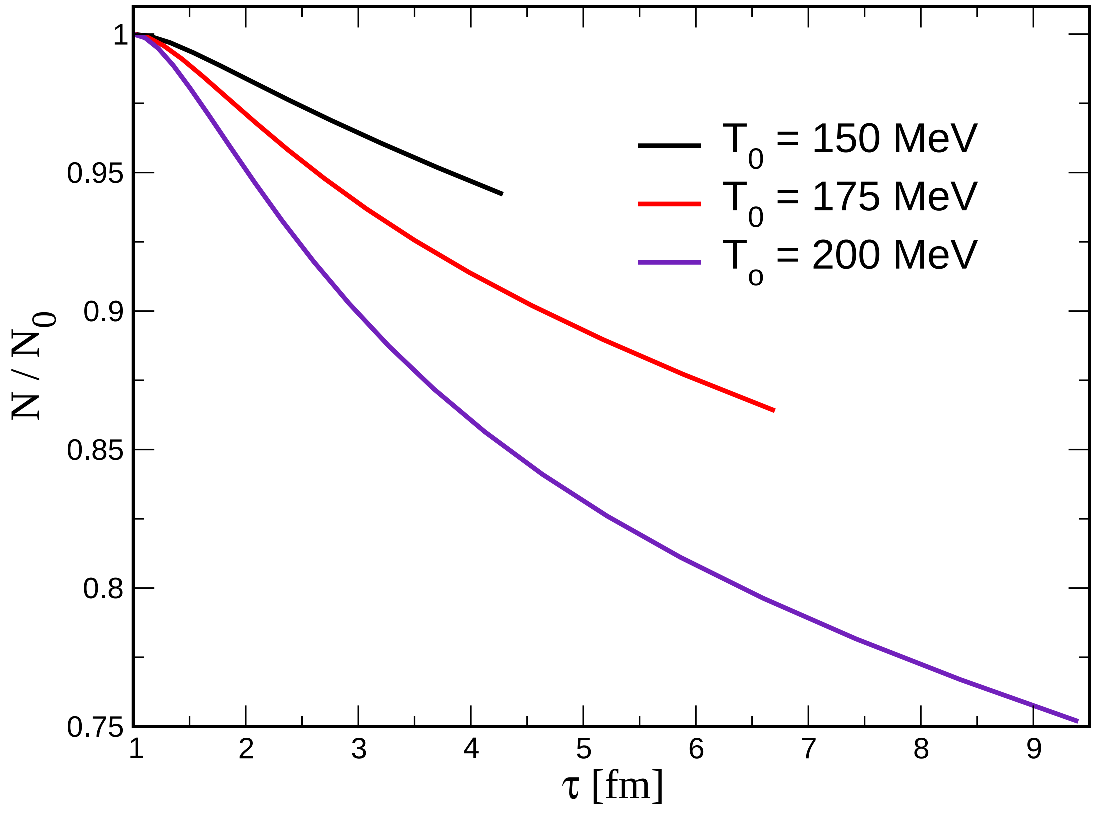
Time evolution of ϕ number in an expanding hadronic fireball

Assumptions:

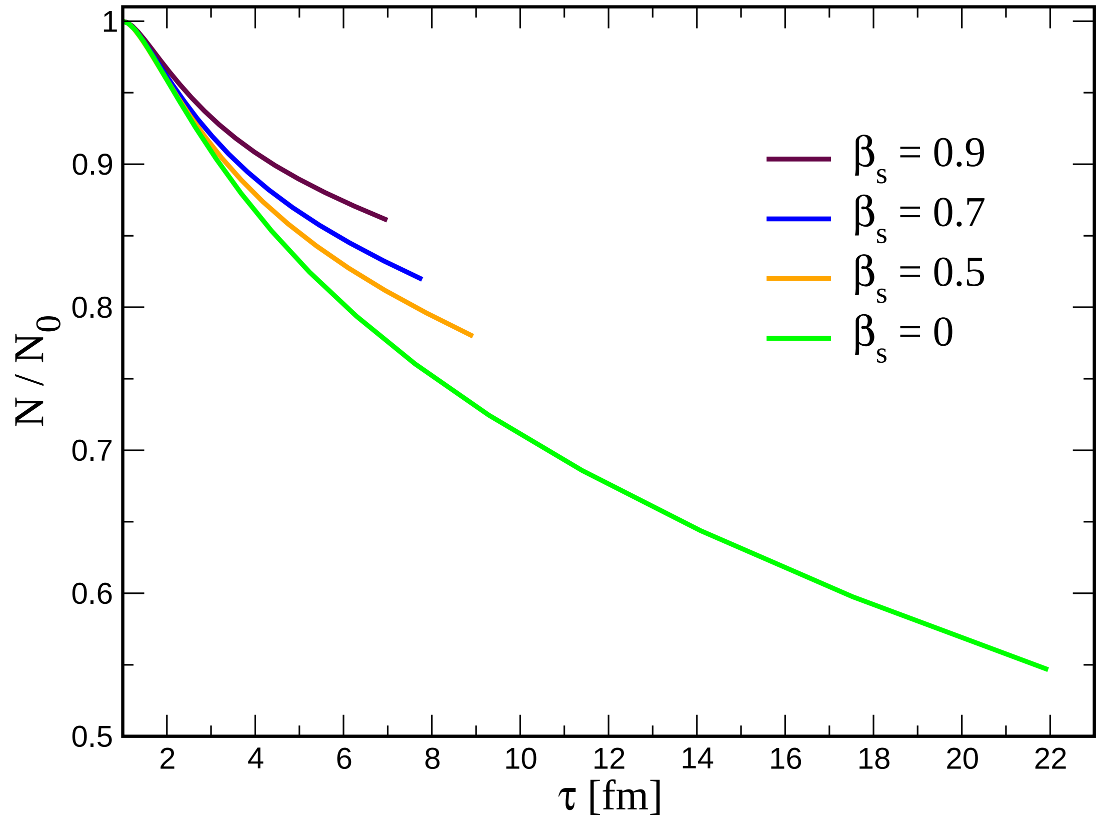
- An ideal gas of π, K, ρ, ω, K^*
- Kinetic equilibrium for all species including ϕ's
- Chemical equilibrium for all species except ϕ's
- Cylindrical symmetry and boost invariance
- Longitudinal and radial transverse expansion
- Entropy conservation
- Rate equation:

$$\partial_\mu \left(n_\phi u^\mu\right) = -\Gamma \left(n_\phi - n_\phi^{eq}\right), \; \Gamma = \Gamma_{coll}(T) + \Gamma_{dec}(T)$$

Different hadronization temperatures



Different flow velocities



Conclusions

- ϕ meson interaction with a hot hadronic gas composed of π, K, ρ, ω, K^*, ϕ has been studied using the Hidden Local Symmetry model.
- Large ϕ collision rates with K, ρ and specially K^*.
- Short mean free path: $1 \le \lambda \le 5$ fm at $200 \ge T \ge 150$ MeV.
- High collision rates cause a reduction of the ϕ number.
- $N/N_0 \sim 5 - 45$ % depending on hadronization and freezeout temperatures, flow velocity and chemical potentials.